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FIELD EVALUATION OF THE ANS-2000 LAND NAVIGATION SYSTEM.(U)
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Technical Report TR-RG-80-23

FIELD EVALUATION OF THE ANS-2000 LAND NAVIGATION SYSTEM

L. J. Little
Inertial Systems Development
Guidance and Control Directorate
US Army Missile Command

July 1980

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document contains the results of a field evaluation of the Singer-Kearfott ANS-2000 Land Navigator System performed by the Guidance and Control Directorate at Redstone Arsenal, AL. The evaluation was performed by Mr. L. Jack Little of the Inertial Systems Development Branch, G&C Directorate, with the support of Mr. John Puzio of Singer-Kearfott.

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20. The overall performance of the system indicates an absolute accuracy of .19% of the distance traveled and a gyrocompassing repeatibility of 1 mil.

CONTENTS

I. INTRODUCTION

A. Singer-Kearfott Division (SKD) consigned an engineering prototype Land Navigation System, model ANS 2000, to the Inertial Systems Development Branch of the Guidance and Control Directorate for the purpose of conducting a field evaluation test and to demonstrate available technology in land navigation hardware to potential using program project offices. The test and concurrent demonstrations were conducted during the period 17-28 March 1980 by John Pizio of SKD and L. Jack Little of the Guidance & Control Directorate, US Army Missile Laboratory, US Army Missile Command.

B. SYSTEM DESCRIPTION

The ANS-2000 Land Navigation System performs the land navigation function by transformation of the vehicle heading, sensed bv a directional gyro, and displacement, sensed by a digital odometer, from polar coordinates into rectangular Universal Transverse Mecator projection coordinates. The rectangular coordinates are displayed in a way to provide the system operator with real-time position and heading of the parent vehicle.

The engineering prototype system submitted by SKD was configured into four packages: (1) the heading reference unit (HRU), (2) the electronic package with the distance measuring unit, and (3) the control display unit. The three units are illustrated in Figures 1, 2, and 3, respectively.

The system is completely autonomous with the exception of the initialization which requires:

- Northing and easting coordinates of the start point.
- Grid declination angle.
- Latitude of the area of operation.
- Scale factor correction for the parent vehicle.

The northing, easting, grid declination and latitude are readily obtainable from a field map. The scale factor correction is a figure empirically determined for the particular vehicle, system interface and surface conditions. Generally a table is developed for the connection to be used for a given set of road or cross-country surface quality. The system has the capability of self-alignment with two levels of accuracy. The first level of accuracy requires a 20-minute gyrocompass routine in the Align North (ALN) mode. The two-position gyrocompassing, requiring 40 minutes, performs the alignment in the Align South (ALS) mode first, which gives an inherent drift factor for the gyro. Upon completing the ALS, the system is switched to ALN where a gyro drift factor, opposite in sign to the ALS gyro drift valve, is

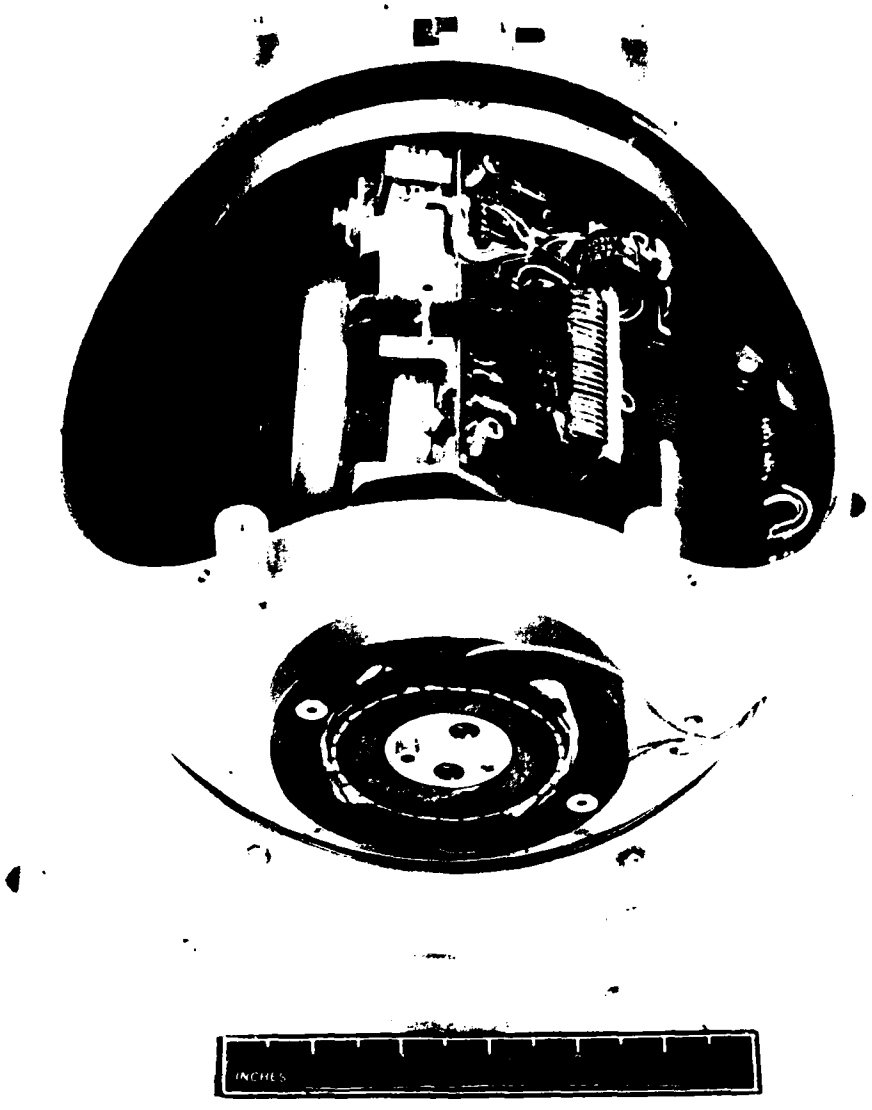
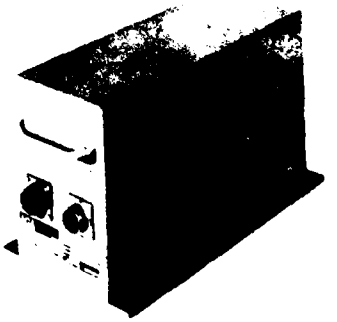


Figure 1. HRU gimbal assembly - top view.



ELECTRONIC PACKAGE

DISTANCE MEASURING UNIT

Figure 2. Electronic unit with distance measuring unit.

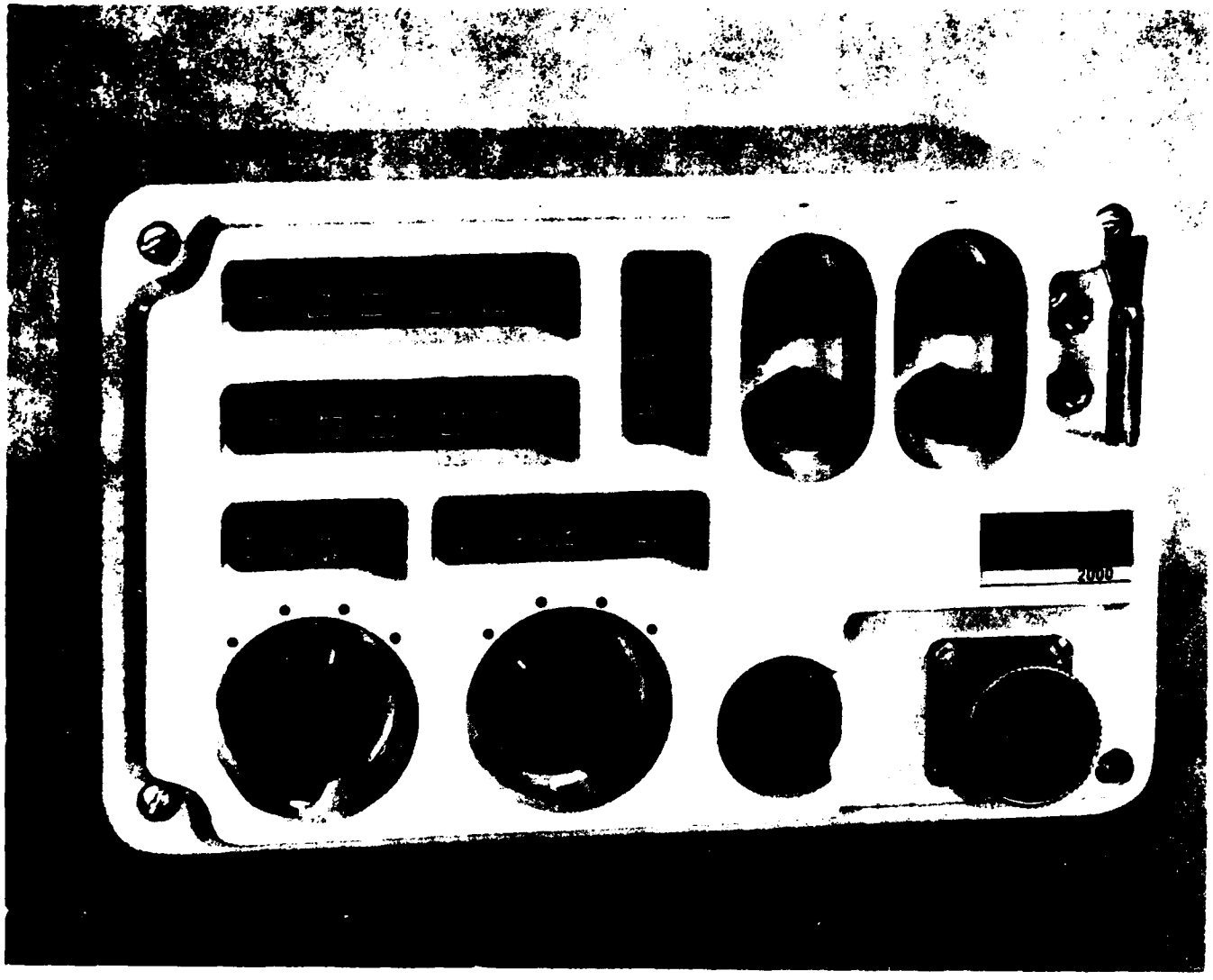


Figure 3. Control and display unit.

obtained. The average value of this drift is derived algebraically and loaded back into the computer to drift-compensate the Directional Gyro mode of operation in azimuth.

Typically, in the single-point alignment, a 2- to 3-mil alignment accuracy can be obtained while 1-mil or better can be achieved in the two-position alignment. Upon completing the two-position gyrocompassing and the drift corrections inserted into memory, the system can be switched to the navigate mode. Once in the navigate mode, the two-degree-of-freedom, dry tuned rotor gyro acts as a directional gyro. The system azimuth angle is encoded with a synchro coupled into the azimuth pivot. In conjunction with the azimuth angle, vehicle displacement is measured by the Distance Transmitter Unit (DTU) which is driven by the vehicle final drive. The DTU generates a pulse train that is processed along with the digitized azimuth to generate a real-time position and heading signal. The position and heading display is updated at a 10-meter rate. When the vehicle is at rest, the present configuration splits the four-digit display to give a 10-meter resolution and a second split of one-meter resolution. Heading is displayed to 1-mil accuracy.

The major portion of the initialization is generally accomplished during the align mode so only initialization of northing, easting, and distance need be accomplished when in the NAVIGATE mode and located at the initialization stake. Once the initial easting and northing values are loaded, navigation can be performed for an undetermined time before realignment. Easting and northing values can be updated very easily when encountering a survey stake or accurately located landmark stake.

B. DATA SUMMARY

The system under test was evaluated for repeatability, absolute accuracy and performance as a function of time. Summarized performance for the 48-km course is given in Table 1.

TABLE 1. SUMMARIZED PERFORMANCE DATA FOR BOTH COURSES

Repeatability	.07% 1 σ	
Absolute Accuracy		
Percent of distance traveled	.19%	meters 1σ
Heading drift (mil/hr)	.524 mean	
	.30 mil/hr	1σ

II. EVALUATION

A. GENERAL

The ANS-2000 field evaluation was partitioned into two major phases. First, a 90-kilometer course was selected to provide point-to-point.

repeatability as a function of time and give a sufficient amount of time to measure gyro drift. Second, a 48-kilometer course was selected to subject the system to a reasonable elevation change and measure absolute accuracy against first-order survey points. The checkpoints used on the long course were established by the system which permits a measure of the system repeatability as a function of distance and time.

The 48-kilometer course contains three first-order survey points, in addition to checkpoints along the course that were established by the system. In all cases the vehicle was halted and positioned over a survey point within 10 centimeters for each measurement in easting and northing. The value in Universal Transverse Mecator projections were recorded at each checkpoint.

The performance was evaluated for repeatibility, in position and gyrocompassing, absolute position error, and percentage of the distance traveled errors.

B. 90-KILOMETER COURSE

1. The ANS-2000 system was aligned each morning. Approximately 60 minutes was required for the alignment since two Align South (ALS) and one Align North (ALN) sequences were conducted with each sequence requiring 20 minutes.

With the system in the GYRO position, a value in mils is displayed and recorded at the end of each sequence, and a value for ALS and ALN is recorded. This data is evaluated to establish a bias or heading correction angle, Ψ, where

$$\Psi = \frac{\text{ALN} - (\text{ALS} - 3200)}{2} \quad \text{mil.}$$

The heading correction angle, Ψ, is then added algebraically to the system heading, HDG, to update the heading to AHV:

$$\text{AHV} = \text{HDG} - (\Psi).$$

AHV is the system heading angle with respect to true North and is used to initialize the ANS-2000 in azimuth. As a rule, the system remained in the NAVIGATE mode for the remainder of the day's operation without additional gyrocompassing or heading update.

2. Once the heading alignment has been completed the vehicle is positioned over the 5400 Astro monument marker where the easting, northing, and distance display registers were initialized for -

Northing	33310 meters
Easting	33200 meters
Distance	00000 meters

The nonrecurring coefficients for the area were:

- Grid correction that adjust for maximum projection convergence
- Latitude of operation
- Scale factor correction

3. The above initialization prepared the system for the navigation problems. The 90-kilometer course (Figure 4) was transversed three times in a clockwise direction with sixteen checkpoints included. The data analysis included determining the root sum square of each checkpoint then calculating a one-sigma value from the three checkpoint radial measurements. The one-sigma value provides a radial error about the mean value of a checkpoint. A value for the relative distance traveled error is derived from:

$$R_i = \sqrt{N_i^2 + E_i^2} \quad \Bigg| \quad \begin{matrix} i = 3 \\ i = 1 \end{matrix}$$

$$\overline{X}_R = \sum_{i=1}^{3} \frac{R_i}{i}$$

$$1\sigma_R = \sqrt{\frac{(R_i - \overline{x}_R)^2}{i - 1}}$$

d = Road distance traveled, meters,

$$\text{percent DT} = \frac{1\sigma_R}{d} \times 100, \text{ and}$$

percent DT = distance traveled percent error.

The three sets of raw data from the 90-kilometer course are contained in Tables 2 through 4. The analyzed data from the raw data is presented in Table 5; however, gyro drift data was measured on the first two data sets (See Tables 2 and 3).

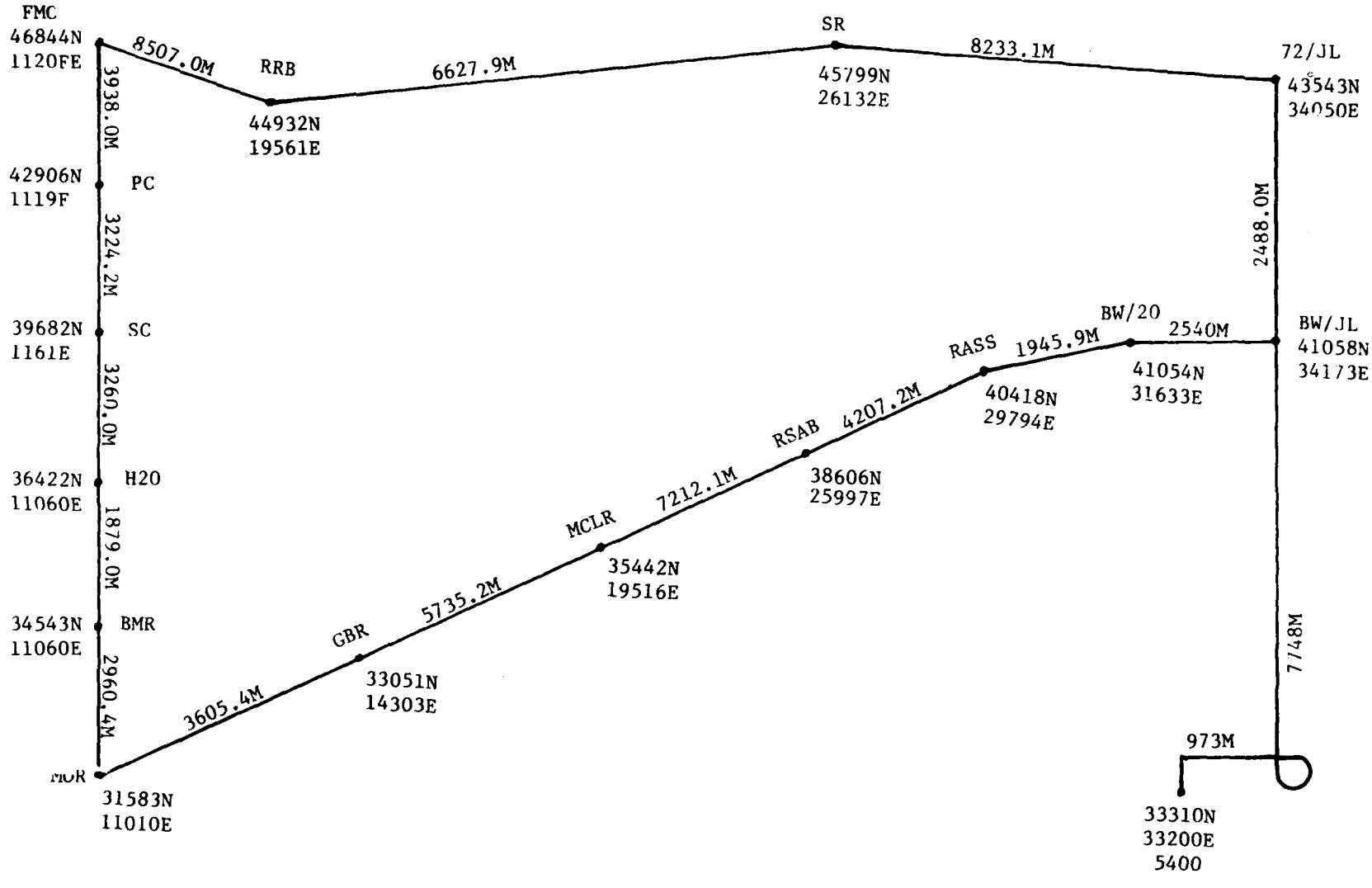


Figure 4. Diagram of 90-km course.

TABLE 2. 90-KM COURSE DATA

Survey point	Problem Duration, min	Distance traveled, kilometers	Northing, meters	Easting, meters
5400			33310	33200
B W/JL	13	10.000	41050	34188
BW/20	17	12.533	41036	31653
RASS	29	14.546	40395	29811
RSAB	37	18.768	38582	26005
MCLR	47	25.984	35438	19511
LBR	53	31.724	33059	14289
MOR	62	37.823	31595	10994
BMR	68	40.769	34523	11043
HZO	76	42.678	36429	11078
SC	82	45.947	39697	11146
PC	89	49.175	42925	11180
FMC	95	53.119	46868	11189
RRB	106	62.582	44951	19556
SR	114	69.316	45819	26140
72/JL	125	77.642	43563	34069
5400	160	89.717	33370	33231

NAV Mode Heading (Time of Operation 160 min) = 1573
GYRO Position (a) 25 min ALN = 1574.5
GYRO Position (a) 25 min ALS = 4773.0

Correction = 1573.75 Drift = $\frac{.042}{2.66 \text{ hr}}$ Deg = $\frac{.015 \text{ deg/hr}}{.27 \text{ mil/hr}}$

Scale Factor CORR = 2.13 percent
LAT = 34.75 deg
GD CORR = 6397 mil

TABLE 3. 90-KM COURSE DATA

Survey point	Problem duration, min	Distance traveled, kilometers	Northing, meters	Easting, meters
5400			33310	33200
BW/20	26	12.540	41064	31615
RASS	30	14.551	40429	29776
RSAB	39	18.763	38617	25978
MCLR	49	25.974	35442	19501
GBR	56	31.711	33043	14288
MOR	63	35.333	31584	10991
BMR	70	38.430	34509	11040
HZO	74	40.337	36415	11072
SC	80	43.595	39672	11138
PC	86	46.819	42895	11174
FMC	93	50.756	46831	11181
RRB	103	59.512	44922	19529
SR	112	66.226	45789	26093
FZ/JL	120	74.530	43536	34006
5400	156	86.894	33352	33161

NAV mode heading (time of operation 156 min) = 6389
GYRO position (a) 25 min ALN = 3189
GYRO position (a) 25 min ALS = 6388

Correction = $\frac{6388.5}{}$ Drift = $\frac{.028 \text{ deg}}{2.6 \text{ hr}}$ = .011 deg/hr or .19 mil/hr

Scale Factor CORR = 2.13 percent
LAT = 34.75 deg
GD CORR = 6397 mil

TABLE 4. 90-KM COURSE DATA

Survey point	Problem duration, min	Distance traveled, kilometers	Northing, meters	Easting, meters
5400			33310	33200
BW/JL		9.947	41066	34158
BW/20	19	12.493	41063	31632
RASS	23	14.502	40429	29794
RSAB	29	18.702	38619	26007
MCLR	40	25.907	35445	19537
GBR	48	31.637	33051	14331
MOR	54	35.265	31569	11044
BMR	60	38.186	34596	11097
HZO	65	40.092	36421	11031
SC	72	43.349	39676	11198
PC	78	46.569	42897	11238
FMC	84	50.505	46832	11250
RRB	95	59.261	44923	19598
SR	102	65.976	45788	26163
7Z/JL	111	74.280	43529	34075
5400	128	85.802	33356	33237

Scale Factor CORR = 2.15 percent
LAT = 34.75 deg
GD = 6397 mil

TABLE 5. 90-KM COURSE SURVEY POINT DATA SUMMARY

Survey point	Distance traveled, kilometers	Northing(N) $\overline{X}_n$, meters	Easting(E) $\overline{X}_E$, meters	1 σ $\overline{X}_i$, meters	% distance, $\frac{1\sigma}{d}$
5400		33310	33200		
BW/JL	9.973	41058	34173	3.4	.03
BW/20	12.522	41054	31633	4.3	.03
RASS	14.533	40418	29794	7.1	.05
RSAB	18.744	38606	25997	13.0	.07
MCLR	25.955	35442	19516	9.1	.03
GBR	31.691	33051	14303	10.0	.03
MOR	36.140	31583	11010	8.1	.02
BMR	39.128	34543	11060	44.0	.11
H20	41.036	36422	11060	8.9	.02
SC	44.297	39682	11161	11.2	.03
PC	47.521	42906	11197	12.5	.03
FMC	51.460	46844	11207	15.5	.03
RRB	60.452	44932	19561	15.9	.03
SR	67.173	45799	26132	20.6	.03
72/JL	75.484	43543	34050	24.7	.03
5400	87.471	33359	33210	28.0	.03

$$\text{Drift} = \frac{.028 \text{ deg}}{2.6 \text{ hr}} = .011 \text{ deg/hr}$$
or .19 mil/hr

The gyro drift in Table 2 is .27 mil/hr and .19 mil/hr in Table 3. The data summary in Table 4 supports the small drift angles evident from data in Tables 2 and 3. Average drift for the 30-minute leg of the course between MOR and FMC would be .013 degrees. The cross track drift attributable to the gyro drift over the nominal 15.319 kilometers would be 15,319 meters tan (.013°/hr x .5 hr) = 1.7 meters, which is a small part of the repeatibility between MOR and FMC shown in Table 5; however, it is evident from the percentage of the distance traveled calculation that the position error is well within specified tolerances.

The repeatibility error in returning to the start point in terms of the distance traveled is .03 percent; however, the absolute error in returning to the 5400 monument for start point is 41 meters or .05 percent of the distance traveled.

C. 48-KILOMETER COURSE

1. The ANS-2000 Land Navigator was initialized for the 48-kilometer course (Figure 5) the same as for the 90-kilometer course. The main advantage in the 48-kilometer course is the survey point accuracy and 300-meter change in elevation between first-order survey points 5400 to MS and MS to PC.

2. Tables 6 through 17 contain the raw data collected from the ANS-2000 during navigation problems over the 48-kilometer course. The tables contain system check point data, northing, easting, time of arrival at a check point, total distance to start point, CORR (scale factor correction), LAT (latitude), GD (grid declination in mils), and gyro-compassing data where available.

Tables 18 through 24 contain the analysis of the data for each check point. The mean and 1-sigma values are calculated from the multiple readings for northing, easting and the root sum square of northing and easting. Where there is a known survey point, as is the case with MS, PC and 5400, an absolute radial error is calculated as well as an absolute easting and northing error. The other check points are evaluated for the worst case relative error;

$$\text{Relative error} = \frac{\bar{X}_R - R_{ss}}{\bar{X}_R} \times 100 \ ,$$

where

$\bar{X}_R$ is the mean root sum square vector, and

R_{ss} is the greatest error vector from the mean.

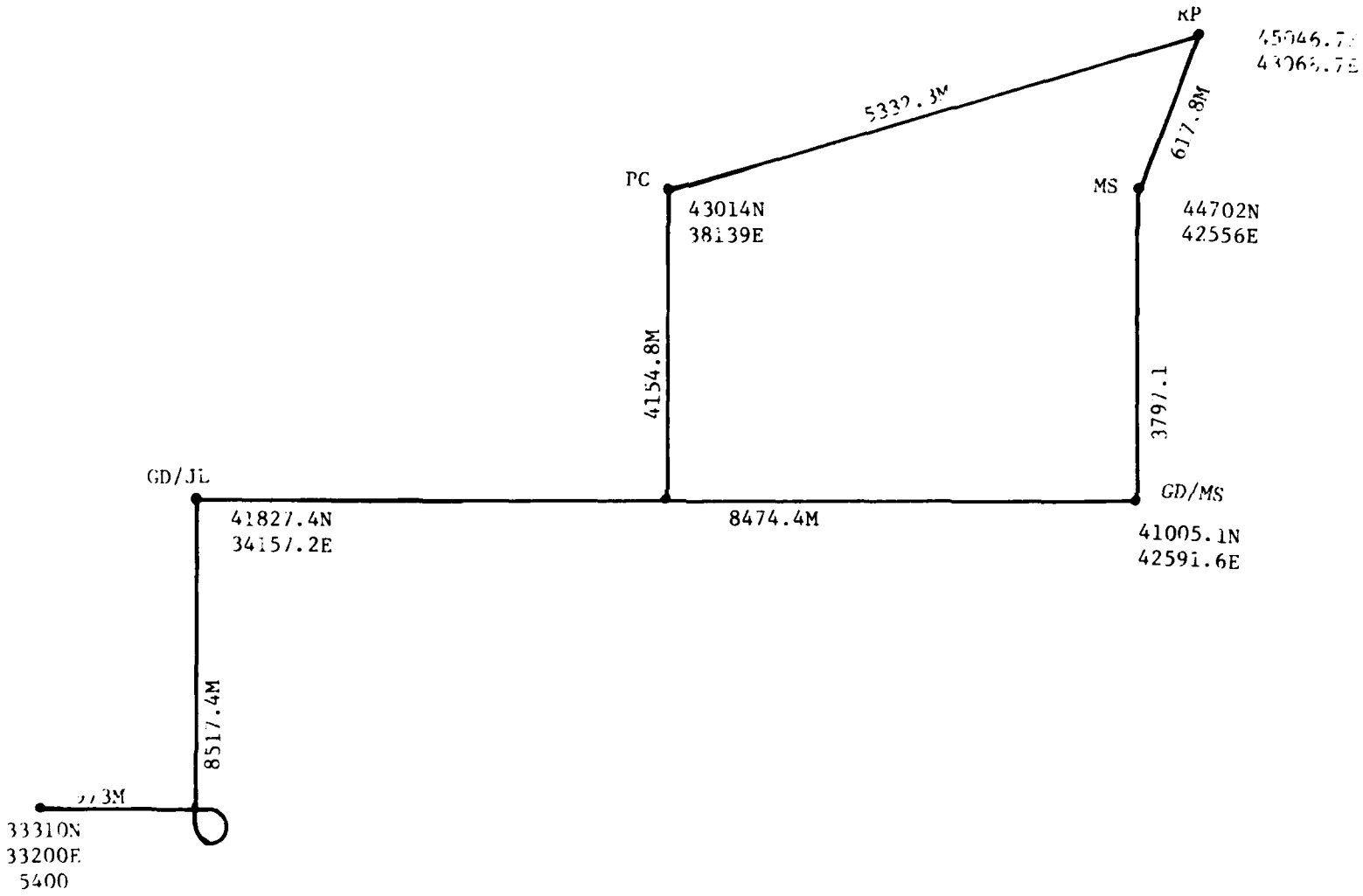


Figure 5. 48-km course.

TABLE 6. PRECISION REPEATIBILITY DATA

Survey point	Time, min	Distance, meter	Northing, meters	Easting, meters
5400	0	0	33310	33209
GD/JL	13	10695	41795	34130
PC	46	32177	43045	38148
GD/JL	56	37925	41810	34160
5400	73	47801	33336	33242
	73	Reset System		
5400	73	0	33310	33200
GD/JL	101	11523	41795	34136
PC	110	16030	43032	38128
GD/JL	120	21779	41799	34138
5400	135	31659	33318	33219
	150	Reset System		
5400	150	0	33310	33200
PC	218	17103	43013	38128
5400	270	32701	33311	33222
	272	Reset System		
5400	272	0	33310	33200
PC	289	16187	42995	38125
5400	309	32062	33293	33230

ALS = 4771.5 mils: 0807 hr
ALN = 1571.5 mils: 0837 hr
Ψ = No correction

Drift = $\frac{.056 \text{ deg}}{6.06 \text{ hr}}$

= 9.2×10^{-3} deg/hr

Post gyro = 1650 mil
ALS = 4852 mil : 1443 hr
ALN = 1650 mil: 1506 hr
Ψ = 1 mil = drift in 6.06 hr

TABLE 7. 48-KM COURSE DATA

Date: 28 Mar 80

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
5400	0	0	33310	33200
GD/JL	13	10695	41795	34130
GD/MS	24	19644	40973	42529
MS	32	24073	44714	42519
RP	36	25516	45030	43005
PC	46	32177	43045	38148
GD/JL	56	37925	41810	34160
5400	73	47801	33336	33242

Scale Factor CORR = 1.65 percent
LAT = 34.75 deg
GD CORR = 6397 mil

TABLE 8. 48-KM COURSE DATA

Date: 26 Mar 80

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
5400	0	0	33310	33200
GD/JL	14	11426	41865	34133
GD/MS	28	20278	41041	42602
MS	34	24784	44814	42595
PC	54	32831	43131	38194
GD/JL	67	38463	41889	34175
5400	82	48280	33364	33248

Scale Factor CORR = 2.15 percent
LAT = 34.75 deg
GD CORR = 6397 mil

Gyro = 6389 mil
ALS = 3188.5 mil 0817
ALN = 6388.5 mil 0838
Ψ = 0.5
HDG = 6388.5

TABLE 9. 48-KM COURSE DATA

Date: 25 Mar 80

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
	0910			
5400	0	0	33310	33320
GD/JL	16	10801	41876	34134
GD/MS	29	19837	41059	42612
MS	37	24318	44832	42600
PC	49	32486	43149	38200
GD/JL	60	38290	41905	34179
5400	76	48239	33382	33253

Post gyro 0073 mil
ALS = 3274 mil 1055 hr
ALN = 0073 mil 1157 hr
Ψ = -0.5 mil
HDG = 0073 mil

Scale Factor CORR = 2.15 percent
LAT = 34.75 deg
GD CORR = 6397 mil

Drift rate = $\frac{1 \text{ mil}}{1.26 \text{ hr}}$ = .79 mil/hr

TABLE 10. 48-KM COURSE DATA

Date: 25 Mar 80

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
	1319			
5400	0	0	33310 3m South bias	33200
GD/JL	14	10775	41861	34132
GD/MS	26	19795	41042	42595
MS	31	24264	44812	42585
RP	37	25717	45129	43075
PC	46	32421	43129	38188
GD/JL	57	38439	41888	34172
5400	70	48369	33370	33246

Post gyro 1605 mil 1434 hr
ALS = 4806 mil 1455 hr
ALN = 1606 mil 1517
ψ = -1.0 mil

Scale Factor CORR = 2.15 percent
LAT = 34.75 deg
GD CORR = 6397 mil

TABLE 11. 48-KM COURSE DATA

Date: 24 Mar 80

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
5400	1311	0	33310	33200
GD/JL		10741	41728	34217
GD/MS		19719	40908	42648
MS		24175	44665	42637
RP		25626	44981	43126
PC		32308	42991	38253
GD/JL		38081	41757	34245
5400	1417	47988	33263	33303

Gyro
ALS = 4753 mil
ALN = 1553 mil
Ψ = 0
HDG = 1549

Post gyro 1606 mil
ALS = 4808 mil
ALN = 1606 mil
Ψ = −0.75 mil
HDG = 1606 mil

Scale Factor CORR = 2.15 percent
LAT = 34.75 deg
GD CORR = 6397 mil

Drift = $\frac{.056 \text{ deg}}{1.76 \text{ hr}}$ = .03°/hr or .57 mil/hr

TABLE 12. 48-KM COURSE DATA

Date: 21 Mar 80

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
5400	0	0	33310	33260
GD/JL	19	10811	41811	34160
GD/MS	31	19825	40994	42620
MS	35	24297	44765	42608
PC		32450	43083	38214
GD/JL	61	38471	41844	34196
5400	73	48396	33330	33266

ALS = 4773 mil
ALN = 1571 mil
Ψ = -1
HDG = 1569

Post gyro 1554 mil
ALS = 4752 mil
ALN = 1554 mil
Ψ = -1 mil
HDG = 1553 mil

Scale Factor CORR = 2.13 percent
LAT = 34.75 deg
GD CORR = 6397 mil

$$\text{Drift} = \frac{1 \text{ mil}}{1.2 \text{ hr}} = .82 \text{ mil/hr}$$

TABLE 13. 48-KM COURSE RAW DATA

Date: 20 Mar 80

Location	Time	Mileage, miles	Distance, meters	Easting, meters	Northing, meters
			Set	Set	Set
5400	9:44	4489.9	0	33200	33310
PC	10:09	4500	16612	38153	43096
PC			Set	38130	43020
MS	10:30	4505.2	25124	42578	44714
PC	10:46	4510.5	33624	38177	43033
5400	11:13	4521.1	51068	33239	33263

ALS = 4773.0 @ 24 min
ALN = 1574.5 @ 20 min

Set SF CORR = 2.13 percent
Adjusted GA increase by 3 mil

Ψ =-0.75 No heading CORR
Scale Factor CORR = 1.60 percent Heavy rain
LAT = 34.75 deg
GD CORR = 6397 mil

TABLE 14. 48-KM COURSE RAW DATA

Date: 19 Mar 80

Location	Time	Mileage, miles	Distance, meters	Easting, meters	Northing, meters
5400	1408	4460.6	0	33200	33310
GD/JL	1422	4467.1	10697	34104	41803
PC	1429	4469.9	15216	38101	43050
PC	Up-date system		Set	38140	Set 43020
MS	1444	4475.1	23689	42569	44716
PC	1459	4480.1	31817	39191	43029
5400	1520	4489.3	46648	33281	33281

CORR = 1.60 percent
LAT = 34.75 deg
GD = 6397 mil

TABLE 15. 48-KM COURSE RAW DATA

Date: 19 Mar 80

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
5400	-	0	33310	33200
GD/JL	1310	10716	41812	34105
GD/MS	1322	19688	41019	42531
MS	1328	24141	44769	42511
PC	1343	32601	43078	38138
5400	1404	48271	33316	33237

Gyro
ALS = 6304.0 mil
ALN = 3102.5 mil
Ψ = .75
HDG = 6300

Scale Factor CORR = 1.60 percent
LAT = 34.75 deg
GD = 6397 mil

TABLE 16. 48-KM COURSE RAW DATA

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
5400	1012	0	33310	33200
PC	1035	16704	43551	37294
PC				
GD/MS	UPDATE		43020	38140
MS	1055	25258	45107	42448
	Adj scale factor 1.60 percent			
			Set values	
MS	1129	32518	44710	42560
PC	1142	43725	43022	38182
5400	1208	49368	33276	33296

Scale Factor CORR = 2.60 percent
LAT = 34.75 deg
GD CORR = 6397 mil

TABLE 17. 48-KM COURSE RAW DATA

Date: 18 Mar 80

Survey point	Time, min	Distance, meters	Northing, meters	Easting, meters
	1244			
5400	0	0	33310	33200
PC	1310	16425	42998	37653
MS	1326	24671	44869	41971
PC	1340	32727	43017	37709
5400	1403	48448	33176	33272

Gyro
ALS = 4708 mil
ALN = 1505 mil
Ψ = -1.5 mil
HDG = 1503 mil

Scale Factor CORR = .85 percent
LATT = 34.75 deg
Grid CORR = 6397 mil

TABLE 18. SURVEY STAKE GD/JL

(N) Northing 41827.4
(E) Easting 34157.2

Northing meters	Easting, meters	Root Sum sq, meters	Distance, meters
41810	34160	53990.6	37925
41495	34136	53963.8	11523
41799	34138	53968.1	21779
41795	34130	53959.9	10695
41865	34133	54016.1	11426
41889	34175	54061.2	38463
41876	34134	54025.3	10801
41905	34179	54076.2	38290
41861	34132	54012.4	10775
41888	34172	54058.6	38439
41428	34217	53963.2	10741
41757	34245	54003.4	38081
41811	34160	53991.3	10811
41844	34196	54039.7	38471
41803	34104	53949.7	10697
41812	34105	53957.3	10716

$\bar{X}_n$ = 41827.4 $\bar{X}_E$ = 34157.2 $\bar{X}_R$ = 54002.3

$1\sigma_n$ = 50.2 $1\sigma_E$ = 38.9 $1\sigma_R$ = 39.8

Worst case relative error = $\frac{\bar{X}_R - R_{ss}}{\bar{X}_R}$ x100 = .09 percent

Percent of distance traveled = $\frac{39.8}{21852}$ = .18 percent

TABLE 19. SURVEY STAKE GD/MS

(N) Northing 41005.1
(E) Easting 42591.0

Northing, meters	Easting, meters	Root Sum Sq, meters	Distance meters
40973	42529	59055.1	19644
41041	42602	59154.8	20278
41059	42612	59174.5	19837
41042	42595	59150.5	19795
40908	42648	59095.8	19719
40994	42620	59135.2	19825
41019	42531	59088.4	19688

$\bar{X}_n$ = 41005.1 $\bar{X}_E$ = 42591.0 $\bar{X}_R$ = 59122.0

$1\sigma_n$ = 52.17 $1\sigma_E$ = 44.9 $1\sigma_R$ = 39.8

Worst case relative error = .11 percent

Percent of distance traveled = $\frac{39.8}{19826.6}$ x 100 = .20 percent

TABLE 20. SURVEY STAKE MS

(N) Northing 44702
(E) Easting 42556

Northing, meters	Easting, meters	Root sum sq, meters	Distance meters
44714	42519	61702.6	24073
44814	42595	61827.4	24784
44832	42600	61843.9	24318
44812	42585	61819.1	24264
44665	42637	61748.5	24175
44765	42608	61800.9	24297
44716	42569	61738.5	23689
44714	42578	61743.2	25124
44769	42511	61736.9	24141

$\bar{X}_n = 44755.7$ $\bar{X}_E = 42578.0$ $\bar{X}_R = 61773.4$

$1\sigma_n = 53.7$ $1\sigma_E = 38.4$ $1\sigma_R = 46.9$

$\Delta_n = \frac{N - \bar{X}_n}{N} \times 100$ $\Delta_n = .12$ percent

$\Delta_E = \frac{E - \bar{X}_E}{N} \times 100$ $\Delta_E = .05$ percent

Worst case absolute error = .20 percent

Percent of distance traveled = $\frac{46.9 \text{ m}}{24318} \times 100 = .19$ percent.

TABLE 21. SURVEY STAKE RP

(N) Northing 45046.7
(E) Easting 43068.7

Northing, meters	Easting, meters	Root sum sq, meters	Distance, meters
45030	43005	62266.6	25516
45129	43075	62386.5	25717
44981	43126	62314.9	25626

$\overline{X}_n$ = 45046.7 $\overline{X}_E$ = 43068.7 $\overline{X}_R$ = 62322.7

$1\sigma_n$ = 75.4 $1\sigma_E$ = 60.7 $1\sigma_R$ = 49.3

Worst case relative error = .10 percent.

Percent of distance traveled = .19 percent.

TABLE 22. SURVEY STAKE PC

(N) Northing 43014
(E) Easting 38139

Northing, meters	Easting, meters	Root sum, sq, meters	Distance, meters
43045	38148	57516.4	32177
43032	38128	57493.5	16030
43013	38128	57479.2	17103
42995	38125	57463.8	16187
43045	38148	57516.4	32177
43131	38194	57611.3	32831
43149	38200	57628.8	32486
43129	38188	57605.8	32421
42991	38253	57545.8	32308
43083	38214	57588.7	32450
43050	38101	57489.0	15216
43029	38191	57533.0	31817
43078	38138	57534.5	32601
43096	38153	57557.9	16612
43033	38177	57526.7	33624

$\bar{X}_n$ = 43059.9 $\bar{X}_E$ = 38165.7 $\bar{X}_R$ = 57539.4

$1\sigma_n$ = 47.7 $1\sigma_E$ = 39.5 $1\sigma_R$ = 48.7

$\Delta_n = \frac{N - \bar{X}_n}{N} \times 100$ Δ_n = .11

$\Delta_E = \frac{E - \bar{X}_E}{N} \times 100$ Δ_E = .07

Worst case absolute error = .25 percent

Percent of distance traveled = $\frac{\sigma_r}{\bar{d}} \times 100 = \frac{48.7}{32489.2} \times 100$ = .15 percent

TABLE 23. SURVEY STAKE 5400

(N) Northing 33310
(E) Easting 33200

Northing, meters	Easting, meters	Root sum sq, meters	Distance meters
33336	33242	47077.8	47801
33318	33219	47048.8	31659
33311	33222	47045.0	32701
33293	33230	47038.9	32062
33364	33248	47101.9	48280
33382	33253	47118.1	48239
33370	33246	47104.7	48369
33263	33303	47069.3	47988
33330	33266	47090.5	48396
33263	33239	47024.0	51068
33281	33281	47066.4	46648
33316	33237	47060.1	48271
33276	33296	47073.5	49368
33176	33272	46985.8	48448

$\bar{X}_n$ = 33305.6 $\bar{X}_E$ = 33253.8 $\bar{X}_R$ = 47064.7

$1\sigma_n$ = 53.5 $1\sigma_E$ = 26.2 $1\sigma_R$ = 33.7

$\Delta_n = \frac{N - \bar{X}_n}{N} \times 100$ Δ_n = .013 percent

$\Delta_E = \frac{E - \bar{X}_E}{N} \times 100$ Δ_E = .16 percent

Worst case absolute error = .18 percent

Percent of distance traveled = $\frac{33.7}{44949.8} \times 100$ = .07 percent.

The percent of the distance traveled error is calculated based on the one-sigma radial value of the root sum square from the easting and northing and the actual distance traveled. Again, the radial value for a first-order survey point produces an absolute error while the other checkpoints produce a relative error.

Table 24 summarizes the checkpoint data derived from the 48-kilometer course. Table 25 gives the gyrodrift data accumulated during the two test courses.

3. The ANS-2000 scale factor was set at 2+ percent for a large majority of the road test; however, the value of the scale factor was reduced to 1.65 percent the last day, which had a significant impact on absolute accuracy. Values of .03 percent for MS and .05 percent for PC were achieved for the two precision points as noted in Tables 6 and 7. The overall data reflects a .2 percent of the distance traveled and absolute error for all cases examined.

III. CONCLUSION

The overall performance of the ANS-2000 reflects position accuracy of .2 percent of the distance traveled. On the long course, repeatibility of the radial vector as a function of the distance traveled produces a nominal .02 to .07 percent error. The gyrocompassing of the system consistently reflected 1-mil bias values with a two-position gyrocompassing. The subsequent gyrodrift also indicated less than 1-mil per hour drift characteristic of all measurements made. System operation, to include initialization and alignment, was very simple and the data easy to read. The time required to align the system with a two-position gyrocompass took approximately 40 minutes; a tactical system would require an alignment time of five minutes or less.

Overall, the system performed satisfactorily and should be considered for further development for Army applications.

TABLE 24. 48-KM COURSE DATA SUMMARY

Survey point	Actual meters	Mean meters	1σ meters	Actual meters	Mean meters	1σ meters	Radial error 1σ meters	% of distance traveled meters	Worst case errors, % meters
[illegible]/IL		41827.4	50.2		34157.2	38.9	39.8	.18	.09
[illegible]/MS		41005.1	52.17		42591.0	44.9	39.8	.20	.11
[illegible]MS	44702	44755.7	53.7	42556	42578.0	38.4	46.9	.19	.20 ABS
[illegible]P		43046.7	75.4		43068.7	60.7	49.3	.19	.10
[illegible]PC	43014	43059.9	47.7	38139	38165.7	39.5	48.7	.15	.07 ABS
#5400	33310	33305.6	53.5	33200	33253.8	26.2	33.7	.07	.18 ABS

* Absolute measure against first-order survey point.

TABLE 25. GYRODRIFT DATA

Date (1980)	Time, hr	Drift, mil	Drift rate, mil/hr
28 Mar	6.06	1	.16
25 Mar	1.26	1	.79
25 Mar	1.16	0	-
24 Mar	1.76	1	.57
21 Mar	1.20	1	.82
20 Mar	2.66	.7	.28
26 Mar	2.6	.5	.13

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